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DETECTION-ESTIMATION SCHEMES FOR UNCERTAIN SIGNALS.(U)
MAY 79 A H HADDAD, H V POOR

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The three primary aspects of the research on the referenced grant are summarized. The first aspect involves the use of combined detection-estimation schemes for state estimation in dynamical stochastic systems with uncertainties. Several different performance criteria such as minimax mean-squared error (MSE) and incremental MSE are applied to the problems of state estimation of systems with uncertainties modeled by parametric bounds or by Markovian jump parameters. The second aspect of this research considers the problem of state estimation for the		

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20. ABSTRACT (continued)

slow modes of hierarchical singularly perturbed linear stochastic systems. The solution to this problem involves a reduced-order detection-estimation approach for near-optimal estimation when the perturbation parameter is small and an alternate superior scheme for the case in which the perturbation parameter is not small. The third aspect of this research considers the problem of state estimation in linear stochastic systems driven simultaneously by Wiener and low-intensity Poisson processes.) Optimal (minimum MSE) causal and linear noncausal filters are seen to perform poorly for these systems and noncausal optimal systems are seen to be intractable. A suboptimal sequential smoothing (SSS) scheme is developed which exhibits superior performance to both optimal causal and linear noncausal filters.

(minimum MSE)

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FINAL REPORT

Covering the Period 22 March 1976-21 March 1979

DETECTION-ESTIMATION SCHEMES FOR UNCERTAIN SIGNALS

Research Supported by

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1. General Summary of Research

The overall objective of this research has been the investigation of detection-estimation schemes for the estimation, filtering, or tracking of systems with uncertainties and/or point inputs. The effort on this grant can be divided into three general areas, each of which is summarized in one of the following subsections. Further details of this work can be found in a number of publications reporting on various aspects of this research. These publications are listed at the end of this summary and copies of most of these have been submitted previously to ARO. Those which have not been submitted are either in press or are attached to this report in the form of appendices.

1.1 State Estimation Using Detection-Estimation Schemes for Uncertain Systems

One of the main aspects of this work involves the use of combined detection-estimation schemes for state estimation in dynamical stochastic systems with uncertainties. Uncertainties are modeled in several different ways. One type of uncertainty model applies to linear stochastic systems with unknown noise covariances. Here, information regarding unknown parameters is assumed to be available in the form of single or multiple bounds on the values of unknown parameters. A weighted minimax mean-squared error cost structure is used for deriving the estimator in this case. Another type of uncertainty model is for systems with unknown parameters which may be assumed to be elements of some compact (or convex) space. For this model, an incremental mean-squared error (IMSE) performance criterion is best applied and leads to a minimax state estimator which can be represented as a combined detector-estimator structure. These results are applied to the problem of state estimation for singularly perturbed systems with unknown perturbation parameter. Another aspect of this area of research involves state estimation for systems with uncertain time-varying jump parameters. Such parameters are modeled as finite-state Markov chains with possibly unknown transition matrices. For this case it is found that the Bayes optimal (MMSE) solution can be obtained in recursive form but requires large storage and computation capability. Thus several suboptimal algorithms are proposed to alleviate this problem and it is found that a detection-estimation scheme is a tractable approximation to the optimal (MMSE) estimator. In all cases of this phase of research it is seen that detection-estimation schemes exhibit a certain degree of adaptivity for large observation records while maintaining desirable small-sample properties. These aspects of the research are summarized in [1] which is attached as Appendix A. Further details of this work may be found in [2]-[10].

1.2 Detection, Estimation, and Order Reduction in Multiparameter Singularly Perturbed Systems

This aspect of the research considers the problem of state estimation for the slow modes of hierarchical singularly perturbed linear stochastic systems. For this problem a reduced-order detection-estimation approach is derived which produces near-optimal estimates in the presence of multiple perturbation parameter uncertainties. It is shown that the proposed scheme is of most value when the estimation problem is one of a steady-state nature. However small-sample (i.e. - transient) performance is derived analytically for the proposed filter. It is also seen that the proposed algorithm always contains a near-optimal filter corresponding to the unknown system perturbation parameters and thus questions of convergence need not be considered. A related problem which is also considered here is that of obtaining a steady-state slow mode estimate for situations in which the perturbation parameter is not small. It is seen that in many such cases, a near-optimal solution exists that is easily implementable and whose performance is superior to the reduced-order filter without a corresponding increase in complexity. Summaries of aspects of this work can be found in [11] and [12] (also included as Appendices B and C, respectively) and in [13] through [16].

1.3 State Estimation for Linear Systems Driven Simultaneously by Weiner and Poisson Processes

In this aspect of the research, the problem of state estimation in linear stochastic systems driven simultaneously by Wiener and Poisson processes is considered. The emphasis is on the case in which the incident rate of the Poisson driving process is low. The minimum-mean-squared-error (MMSE) filtering equations are derived for such situations via the Doleans-Dade and Meyer differentiation rule for discontinuous semimartingales and the corresponding basic filtering theorem for white Gaussian observation noise. These optimal filters are seen to be solutions to nonclosed sequences of differential equations. A performance analysis of such filters and of optimal linear filters for the low-incident-rate case leads to the conclusion that causal filters and linear noncausal filters are inherently unsuitable for state estimation in this class of systems. Because of this unsuitability, a noncausal, nonlinear, suboptimal detection-estimation algorithm for state estimation is developed based on a strategy combining linear conditional estimation with the detection and estimation of the incident times and marks of the Poisson input process. A first-order approximation technique is also developed to reduce the error propagation effects that result from the sequential structure of the approach. Both analytical and numerical performance analyses of the proposed scheme indicate that, for low Poisson intensity, the proposed suboptimal smoother performs better than both the optimal causal filter and the optimal noncausal linear filter. Details of this work are included in [17] and [18] (Appendix D) and in [19] and [20].

2. List of Manuscripts Submitted or Published under ARO Sponsorship

During Grant Duration

- [1] A. H. Haddad and J. K. Tugnait, "On state estimation using detection-estimation schemes for uncertain systems," Proc. 1979 JACC, June 1979, Denver, Colo. (see Appendix A).
- [2] R. A. Padilla, "On detection-estimation schemes for signals with uncertain models," Ph.D. Thesis, Report R-736, Coordinated Science Lab., Univ. of Illinois, Urbana, July 1976.
- [3] A. V. Sebald and A. H. Haddad, "Robust state estimation in uncertain systems: Combined detection estimation with incremental MSE criterion," IEEE Trans. Automatic Control, AC-22, pp. 821-825, Oct. 1977.
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- [5] J. K. Tugnait and A. H. Haddad, "On state estimation for linear discrete-time systems with unknown noise covariances," IEEE Trans. Automatic Control, AC-24, April 1979.
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- [8] J. K. Tugnait and A. H. Haddad, "State estimation under uncertain observations with unknown statistics," IEEE Trans. Automatic Control, Vol. AC-24, April 1979.
- [9] J. K. Tugnait and A. H. Haddad, "Adaptive estimation in linear systems with unknown, Markovian noise statistics," Proc. 1978 Conference on Information Sciences and Systems, March 1978, Johns Hopkins University.
- [10] A. V. Sebald, "On robust state estimation for uncertain systems," Ph.D. Thesis, Coordinated Science Lab., Univ. of Illinois, Urbana, Sept. 1976.
- [11] D. Altshuler and A. H. Haddad, "A detection-estimation scheme for hierarchial singularly perturbed systems," Proc. 1979 Conference Information Sciences and Systems, March 28-30, 1979, Johns Hopkins University (see Appendix B).

- [12] D. Altshuler and A. H. Haddad, "Series expansions of singularly perturbed linear systems with applications to estimation," Proc. 1979 JACC, June 1979, Denver, Colo. (see Appendix C).
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- [14] A. H. Haddad and P. V. Kokotovic, "Stochastic control of linear singularly perturbed systems," IEEE Trans. Automatic Control, AC-22, pp. 815-821, Oct. 1977.
- [15] A. Haddad, "On singular perturbations in stochastic dynamic systems," Tenth Asilomar Conference on Circuits, Systems and Computers, pp. 94-98, Nov. 1976.
- [16] H. K. Khalil, A. H. Haddad and G. L. Blankenship, "Parameter scaling and well-posedness of stochastic singularly perturbed control systems," Proc. Twelfth Asilomar Conference on Circuits, Systems, and Computers, pp. 407-411, Nov. 1978.
- [17] S. Au and A. H. Haddad, "Suboptimal sequential estimation-detection scheme for Poisson driven linear systems," Information Sciences, Vol. 16, pp. 95-113, 1978.
- [18] S. P. Au, A. H. Haddad and H. V. Poor, "State estimation for linear systems driven simultaneously by Wiener and Poisson processes: I - Optimal scheme," submitted to IEEE Trans. Automatic Control (see Appendix D).
- [19] S. P. Au, A. H. Haddad and H. V. Poor, "State estimation for linear systems driven simultaneously by Wiener and Poisson processes: II - Suboptimal scheme," submitted to IEEE Trans. Automatic Control (see Appendix D).
- [20] S. P. Au, "State estimation for linear systems driven simultaneously by Wiener and Poisson processes," Ph.D. Thesis, Report R-836, Coordinated Science Lab., Univ. of Illinois, Urbana, Dec. 1978.

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